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REAL TIME CONTOUR LINE GENERATION

INVENTOR


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Jenny Larsen


Date

H0006457**REAL TIME CONTOUR LINE GENERATION**

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BACKGROUND OF THE INVENTION

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Field of the Invention (Technical Field):

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The invention relates to computer graphics and more particularly to computer graphics as utilized in digital map systems in aircraft avionics, consumer mapping devices or the like.

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Background Art:

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The ability to display a dynamic 2 dimensional contour line as part of a real time map display system requires the ability to generate the image from a set of grided elevation data points. The present invention provides real time generation of the contour line image without requiring either preprocessed contour line images or specific electronic hardware as the prior art requires. This would provide the necessary performance to display the digital map contour lines in real time at a lower cost and in a smaller form factor.

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One prior art device is disclosed in US Patent 4,823,287 entitled "Digital Contour Line Generator". This device is an aircraft digital map systems that uses specific hardware to process the terrain information and requires specific hardware components. This limits the range of platforms on which the solution can be utilized, as not all are suitable for the addition of a hardware-based solution. Additionally, the cost of adding hardware either in new design or retrofit is more expensive than a solution, which can be implemented as a software only solution. Other prior art devices pre-generate the images and load them into mass storage rather than generating them on the fly. The primary disadvantage of pre-generating by any process is that it limits the geographic area which can be displayed. Furthermore, it does not allow the dynamic modification of the contour line

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interval, and requires mission planning or similar devices to generate and
2 load the contour plot images into the digital map system

4 In addition to the prior art apparatuses described above, the
“marching squares” algorithm is a common knowledge algorithm in the field
6 of computer graphics, which can be used to generate contour line images.
The existing art marching squares algorithm generates contour lines by
8 evaluating each set of 4 data points against a contour elevation value. As
shown in Fig. 1, data from the input NxM matrix **124** is processed in sets of
10 four data points **146**. For each set of 4 data points, each point is determined
to be inside or outside the contour line **138**, where inside and outside is
12 determined by comparing each scalar data point value with the contour
elevation value. The combination of inside and outside points is then
14 encoded such that the encoding selects one of the 16 possible combinations
130 that a contour line can cross a set of 4 data points **146**.

16

Using the selected intersection pattern **130**, the intersection points
18 **126** and **128** are calculated via linear interpolation. The intersection points
126 and **128** are then used as endpoints **140** and **144** of a line segment **142**
20 drawn on the output image **132**. This process is repeated for each set of four
neighboring data points, for each contour elevation to be displayed on the
22 output image. However, the marching squares algorithm does not provide
the performance required for real time, dynamically updated displays on
24 state of the art digital map hardware platforms. In addition, the marching
squares approach generates extraneous data by calculating more detailed
26 information than is needed for a digital map contour image.

28 Therefore, the prior art approaches cannot meet both the
performance requirements and the cost requirements. Approaches that
30 meet performance require expensive additional hardware, whereas
solutions, which do not require added hardware can not meet real time
32 dynamic performance requirements. Existing methodologies for generating
contour lines focus on interpolation of data for optimal image quality, but
34 cannot adequately meet the needs for a fast moving digital map.

2 The present invention maintains state information as it processes
data, which results in a reduced number of operations required to generate a
4 contour line image. This allows it to operate faster, and without requiring
additional hardware devices. Thus, the faster performance of the invention
6 allows real time dynamic contour line generation on commodity hardware, at
a lower cost than the prior art methods.

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10 SUMMARY OF THE INVENTION (DISCLOSURE OF THE INVENTION)

12 An apparatus and method for providing real time generation of a
14 contour plot image of contour lines without requiring either preprocessed
contour line images or specific electronic hardware is disclosed. The
16 improved performance of the present invention provides the ability to display
digital map contour lines in real time at a lower cost and in a smaller form
18 factor than any of the prior art devices. The present invention maintains an
ongoing current contour line state, which enables fast determination of
20 contour line points without explicit comparison of multiple neighboring
elevation points.

22 A primary object of the present invention is to generate contour plot
24 images comprised of contour lines using gridded digital terrain data.

26 Another object of the present invention is to generate a contour line
image at a real time performance level.

28 A further object of the present invention is to generate a contour line
30 image using general-purpose commodity computer hardware.

32 Yet another object of the present invention is to generate a contour
line image that can be integrated with a moving digital map system.

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2 An advantage of the invention is that it requires few system
resources, thus it does not require specialized computer hardware to operate
effectively.

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6 Another advantage of the invention is that it allows for dynamic
updating of the contour line interval.

8 A further advantage is that contour lines can easily be enhanced by
adding a simple weighted anti-aliasing to the invention, thereby eliminating
10 the need for separate anti-aliasing.

12 The invention provide an additional advantage in that the solution is a
cost-effective means of adding a dynamic contour plot capability to new and
14 existing digital map systems

16 Other objects, advantages and novel features, and further scope of
applicability of the present invention will be set forth in part in the detailed
18 description to follow, taken in conjunction with the accompanying drawings,
and in part will become apparent to those skilled in the art upon examination
20 of the following, or may be learned by practice of the invention. The objects
and advantages of the invention may be realized and attained by means of
22 the instrumentalities and combinations particularly pointed out in the
appended claims.

24

26 BRIEF DESCRIPTION OF THE DRAWINGS

28 The accompanying drawings, which are incorporated into and form a
part of the specification, illustrate several embodiments of the present
30 invention and, together with the description, serve to explain the principles of
the invention. The drawings are only for the purpose of illustrating a
32 preferred embodiment of the invention and are not to be construed as
limiting the invention. In the drawings:

Fig. 1 shows the prior art marching squares methodology for contour
2 imaging.

Fig. 2 depicts simultaneous row-column processing as used in the
4 preferred embodiment.

Fig. 3 shows the preferred method of processing elevation by row.

6 Fig. 4 shows the preferred method of contour anti-aliasing.

8

10 DESCRIPTION OF THE PREFERRED EMBODIMENTS
(BEST MODES FOR CARRYING OUT THE INVENTION)

12 The present invention is a software implementation of a process that
transforms input elevation data into a contour plot image, which is comprised
14 of a set of contour lines. The contour plot can be generated from available
grided elevation data or the like. The algorithm used in the process allows
16 for real time display such as a real time digital moving map system.

18 The invention generates an contour line image from an NxM elevation
data set **104** as shown in Fig. 2, where N is the number of rows and M is the
20 number of columns in the input and output data. The data may be
processed in row major or column major ordering. Row major, top to bottom
22 ordering is used for the following description. The resultant image **106**
contains the set of contour lines, which are multiples of the contour interval
24 value provided to the invention. The contour interval **148** may be any value.
Thus, an image representing, for example, the contours every 100 m is
26 generated by using a contour interval value of 100 for an elevation data set
in units of meters.

28

M+1 temporary memory storage locations are required for processing,
30 one for each M columns **100** plus 1 for the current row **102**. These are
referred to as the row and column base elevation values respectively. These
32 values maintain a current contour line state, which enables fast
determination of contour line points without explicit comparison of multiple

neighboring elevation points. An NxM output storage location is required to
2 hold the resultant contour line image **106**.

4 The base elevation values per column **100** are set to the largest
contour interval multiple, which does not exceed the elevation value of the
6 corresponding column of the first data row **114** of input data **104**. The
column base elevation set **100** is initialized only once, before processing of
8 the elevation data begins. The row base elevation value **102** is set at the
start of processing each row to the contour elevation closest to but not
10 exceeding the first elevation value in the row.

12 The data is scanned in row major order beginning with the first
column of the first row in the elevation data set. As each data point is
14 encountered, if the elevation data value exceeds either the row base
elevation **102** or column base elevation **100** value plus the contour interval,
16 then a contour line point has been detected. A corresponding pixel in the
NxM output image memory **106** is turned on and both the row and column
18 base elevation values are set to the contour interval multiple closest to but
not to exceed the elevation data value. This can be expressed
20 algorithmically as:

if (absolute value(elevation – row base elevation) > contour delta OR
22 absolute value(elevation – column base elevation) > contour delta)
then
24 set pixel in output image memory at row, column
set row base elevation to (elevation / contour interval) * contour
26 interval
set column base elevation to (elevation / contour interval) * contour
28 interval

30 For example, as shown in Fig. 3, elevation point **108** of the input data
158 exceeds the current row base elevation **164** by a value greater than the
32 contour interval **148**. Therefore, a pixel in the output image **106** row **114** and
column **110** corresponding to the elevation data point row and column **108** is
34 given a non-blank value, i.e. the pixel is drawn. The row base elevation **102**

and the column base elevation **100** are both set **162** to the highest contour
2 interval multiple less than the elevation data point **108**. This generates the
points for all contour line components, which are on the rising slope of the
4 input elevation data.

6 Similarly, if the input elevation value is less than either base elevation
value **100** or **102**, then a corresponding pixel in the NxM output **106** is turned
8 on. Algorithmically this can be expressed as:

if (elevation – row base elevation) < 0 OR
10 elevation – column base elevation) < 0) then
set pixel in output image memory at row, column
12 set row base elevation to (elevation / contour interval) * contour
interval
14 set column base elevation to (elevation / contour interval) * contour
interval

16
As an example, the elevation point **112** is below the current row base
18 elevation value **166**, therefore the corresponding pixel memory **106** is set to
an on state, and the row and column base elevation values are set to the
20 largest contour interval multiple which does not exceed the elevation data
value. This generates the points for all contour line components, which are
22 on the declining slope of the elevation data.

24 By maintaining the two dimensional base elevation values, the row
base elevation **102** and the column base elevation set **100**, the present
26 invention eliminates the need to sample multiple neighboring data points as
is performed by all present state of the art methods. The two base elevation
28 elements combine to maintain a continuously updated state of the elevation
data scan. This allows the invention embodied as software on a general
30 purpose processor to provide real time dynamic performance while only
requiring M+1 memory locations. Thus, the present invention may be
32 utilized in any form of digital map system, which contains elevation data and
M+1 available temporary storage locations. The present invention provides

performance on a 366Mhz PowerPC processor to support a 20Hz update
2 rate using a 1024x1024 elevation data set.

4 The present invention is most preferably embodied as software
executing on a general purpose processor. This embodiment provides the
6 advantage of a cost effective real time contour line solution. It is also an
advantage that it can be ported to a variety of digital map systems in an
8 easier fashion than a solution requiring a specific hardware component
would. Another advantage of the invention is that it can be embodied as
10 firmware or hardware with associated higher performance, providing
flexibility. The method of the invention provides further advantage in that it
12 generates closed loop contour lines, thereby providing an accurate contour
line representation.

14
The invention can be modified to provide fast anti-aliasing of the
16 contour lines, as shown in Fig. 4. Anti-aliasing smoothes the appearance of
lines, removing the jagged appearance that can occur in computer
18 generated images. When a contour line crossing is detected, the distances
120 and **152** from the pair of elevation data points **118** and **150** to the
20 contour line elevation **168** are used as weights **122** and **154** for the pixel
intensities. That is, given two data points A **118** and B **150**, the weighting
22 **120** and **152** for each output pixel **122** and **154** are given as:

$$\text{Distance} = \text{Elevation_B} - \text{Elevation_A}$$

$$\text{Weight_A} = (\text{Contour Line Elevation} - \text{Elevation_A}) / \text{Distance}$$

$$\text{Weight_B} = (\text{Elevation_B} - \text{Contour Line Elevation}) / \text{Distance}$$

26

The invention may be expanded to operate on a 3-dimensional input
28 data set. Given an NxMxZ data set, it would produce a NxMxZ output
representing the contour shape in 3-dimensions. This modification would
30 require N + M + 1 memory locations for maintaining the historical elevation
values. The data would be scanned by row, column and depth in the same
32 manner as for 2 dimensions. For each data point, comparisons with the 3
base elevation values would be performed to determine contour line points.
34 This modification would result in degraded performance in real time systems.

Such a modification of the invention would be useful to display seismic or
2 atmospheric data.

4 The primary use of the invention is for generating contour lines for
digital map systems. Given that the contour lines represent the slope, or
6 steepness of the input data set, the invention can be further utilized to
generate slope images of any NxM data set. For instance, the invention can
8 be used to generate contour images of business data such as income,
revenue, or others arranged in a 2 dimensional format. The contour image
10 generated by the invention represents the rate of change in the data set
values. Thus the invention could be used for real time display of business
12 financial information.

14 The invention requires that sufficient memory locations to store the
NxM output image and $M + 1$ temporary memory locations are available.
16 The real time performance of the invention is dependent on the particular
physical processor being used. It is suitable for real time performance on
18 any state of the art processor used in digital map systems.

20 Although the invention has been described in detail with particular
reference to these preferred embodiments, other embodiments can achieve
22 the same results. Variations and modifications of the present invention will
be obvious to those skilled in the art and it is intended to cover in the
24 appended claims all such modifications and equivalents. The entire
disclosures of all references, applications, patents, and publications cited
26 above, are hereby incorporated by reference.